Physical Mixing and Morphology of Soot

Swarup China
Rajan Chakrabarty, Kyle Gorkowski, Neila Salvadori, Allison Aitken, Bradley Flowers, Sumit Kumar, Jacques Huber, Katja Dzepina, Chris Owen, Mike Dziobak, Bo Zhang, Lynn Mazzoleni, Claudio Mazzoleni

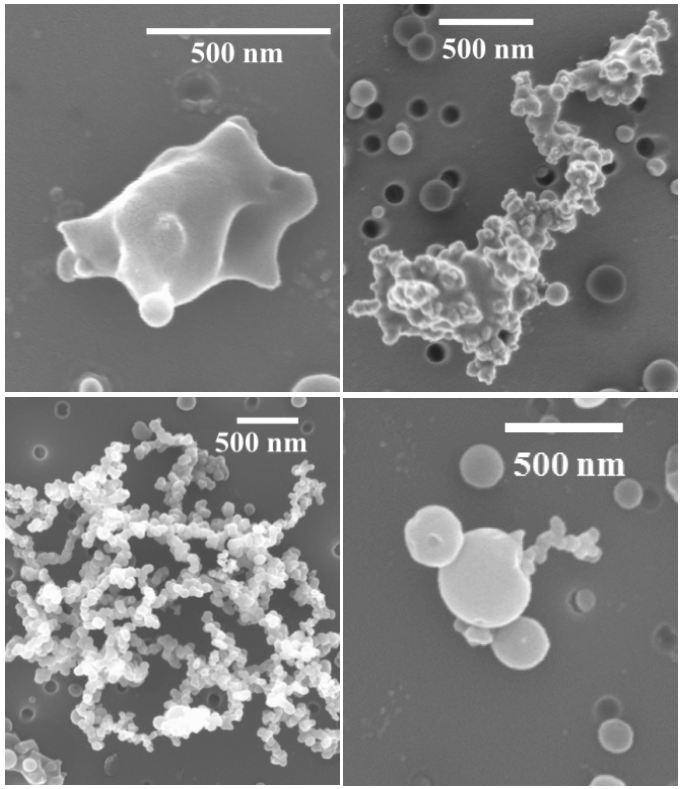
Many others: Rahul Zaveri, Manvendra Dubey, Tim Onasch, Scott Hendron, Leah Williams, Detlev Helmig, Paulo Fialho, Hans Mosmüller, Pat Arnott….

Richard Honrath (deceased 2009)

ASR Atmospheric System Research
U.S. DEPARTMENT OF ENERGY | Office of Science
Michigan Tech
Michigan Technological University

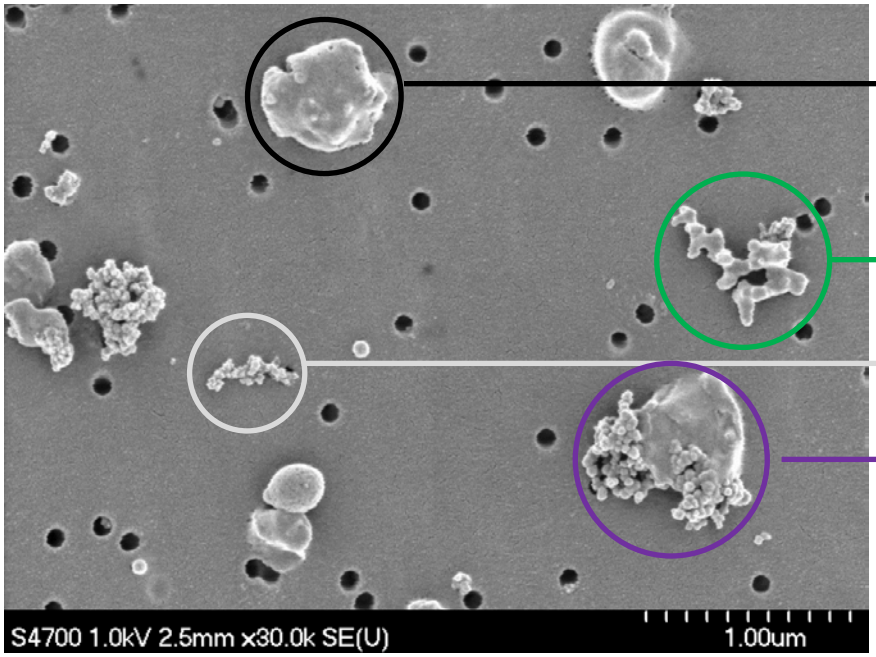
Physical Mixing and Morphology of Soot:

Why studying it?



- Surface reactions?
- Ice nucleation?
- Optical properties
- Remote sensing
- Interpretation of data (e.g. SP2)
- …

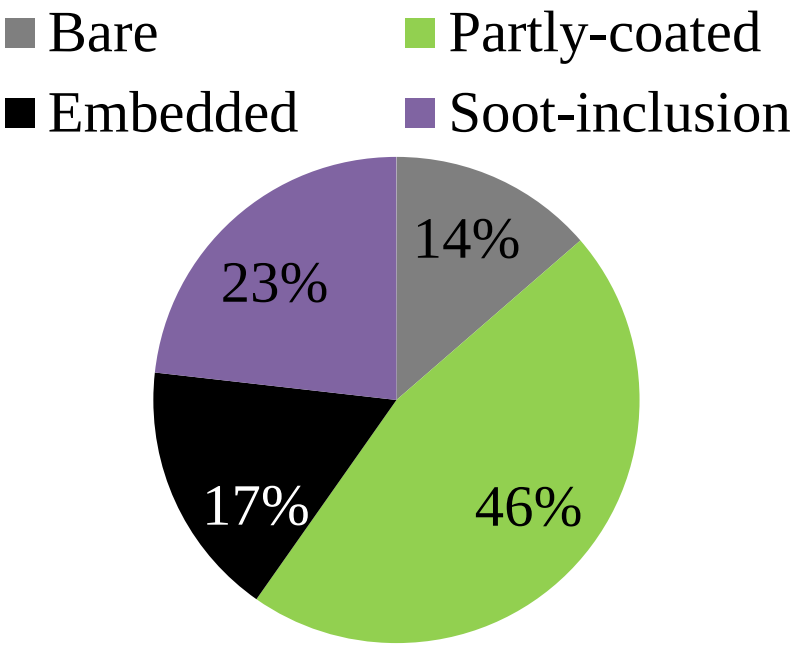
Mixing & Morphology



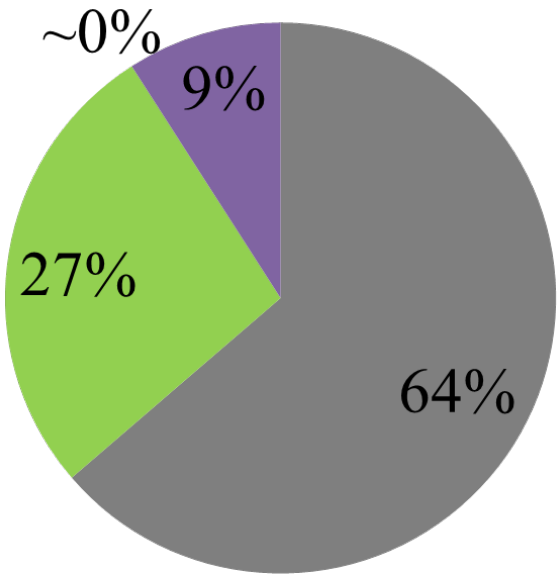
ClearfLo

January 31,2012, Detling

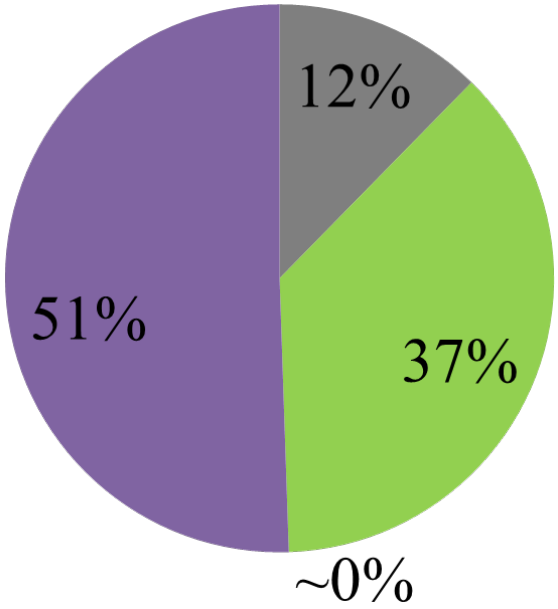
61% soot of the total number of particles



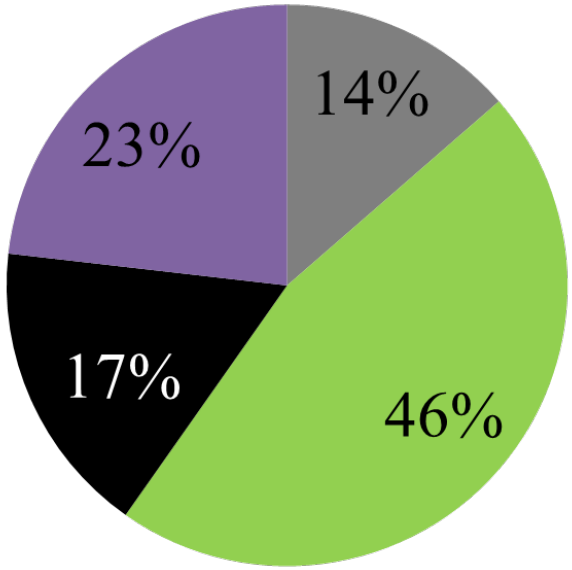
soot particles classified ~310



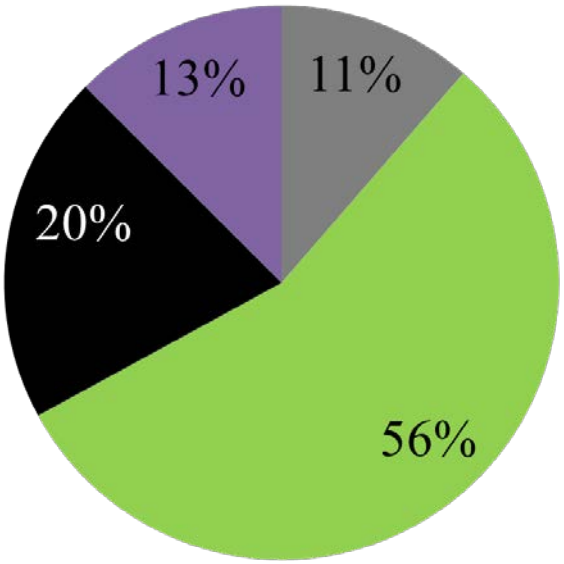
MILAGRO (T0)



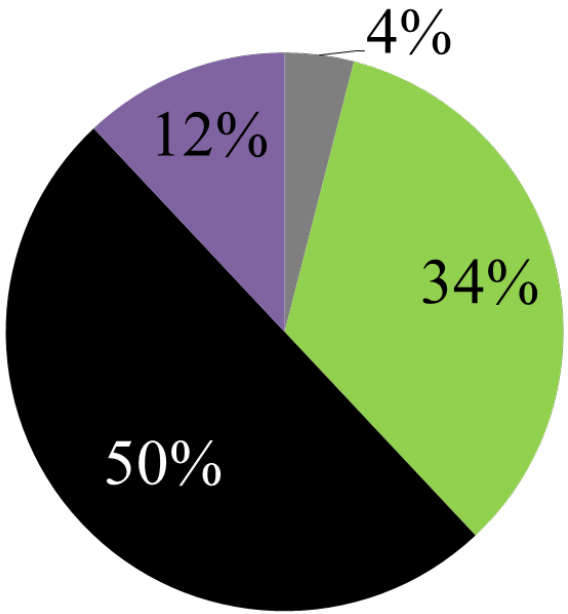
MILAGRO (Pedegral)



ClearfLo



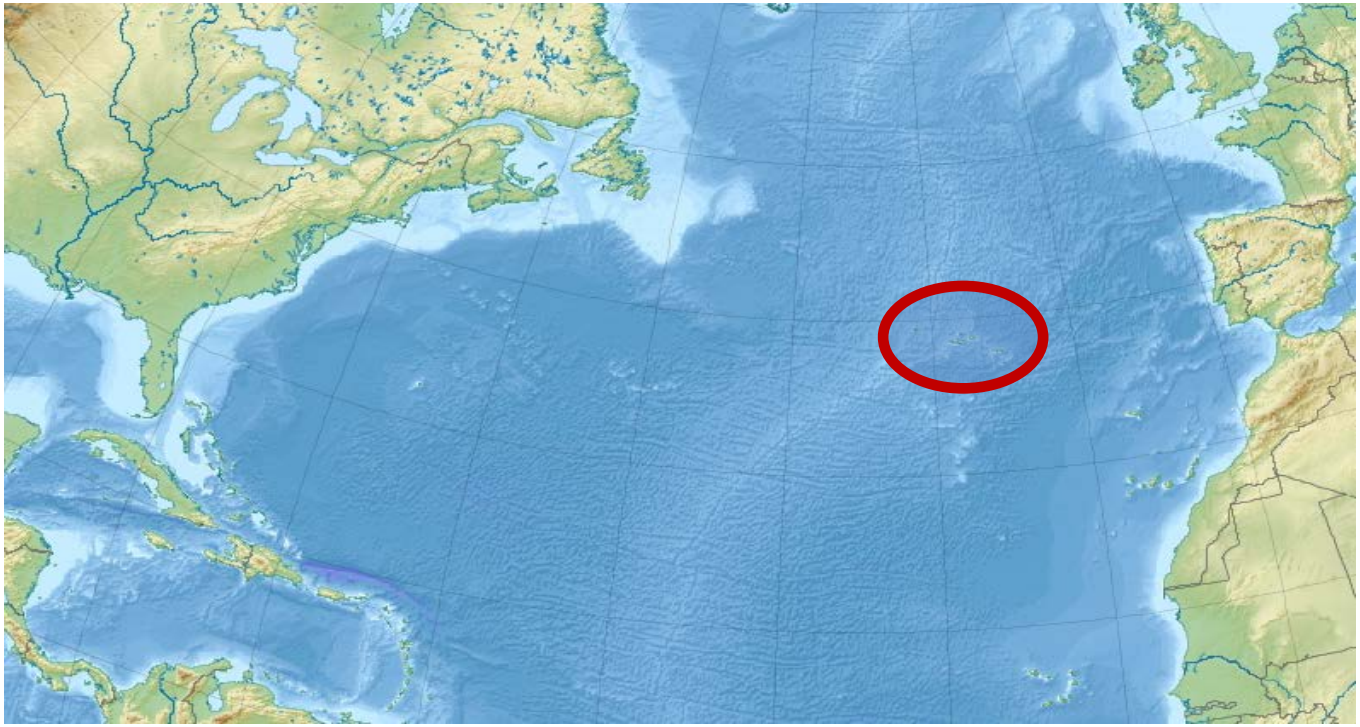
Pico (Azores)



Biomass (Las Conchas fire)

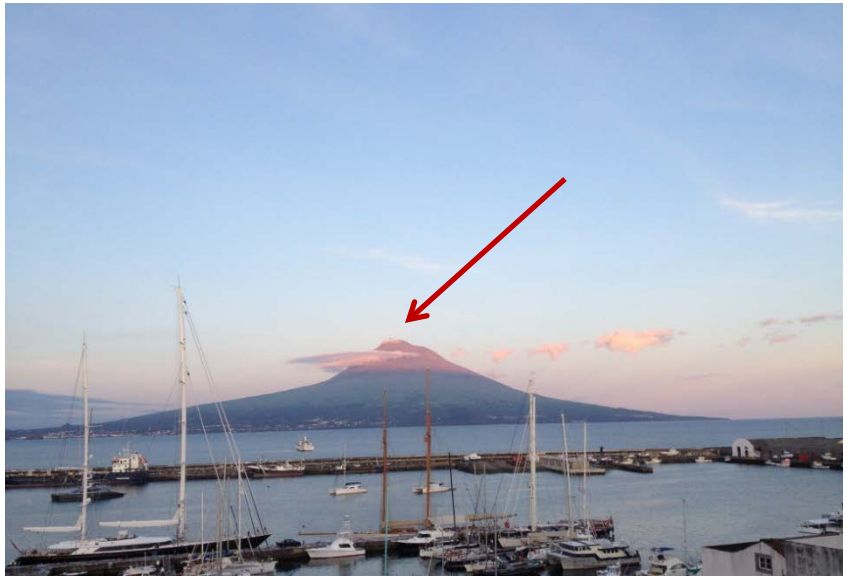
- Bare
- Partly-coated
- Embedded
- Soot-inclusion

Pico Mt. Observatory - Azores



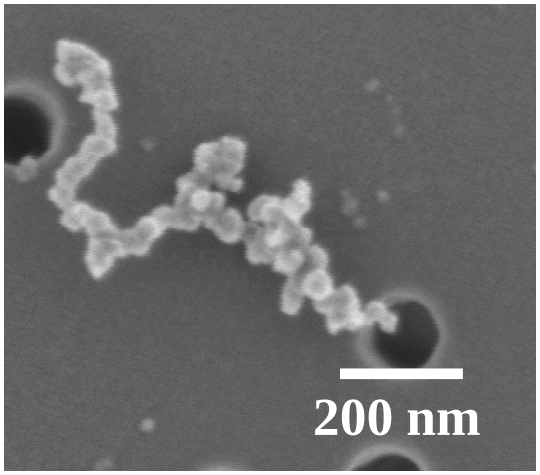
- 2225 m asl
- Free troposphere
- Typically: Long range transport from North America

Poster 151 Room 23

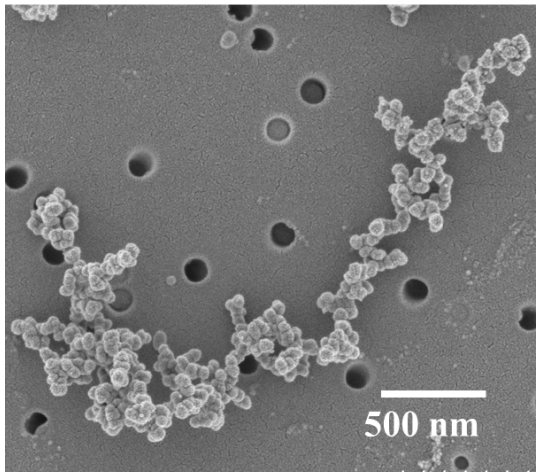


Mixing & Morphology

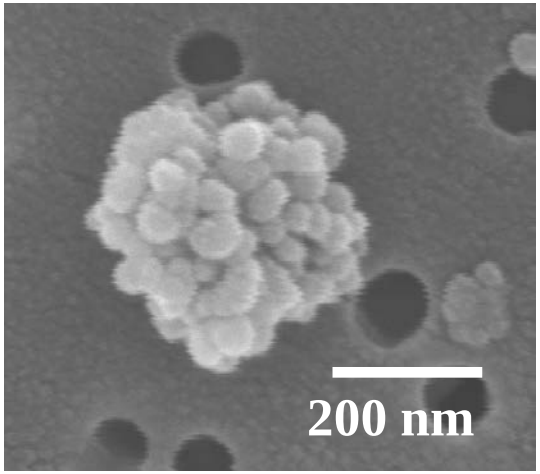
Soot particle morphology evolution:
Fresh vs. aged long range transported



Ann Arbor
(Freeway on-ramp)



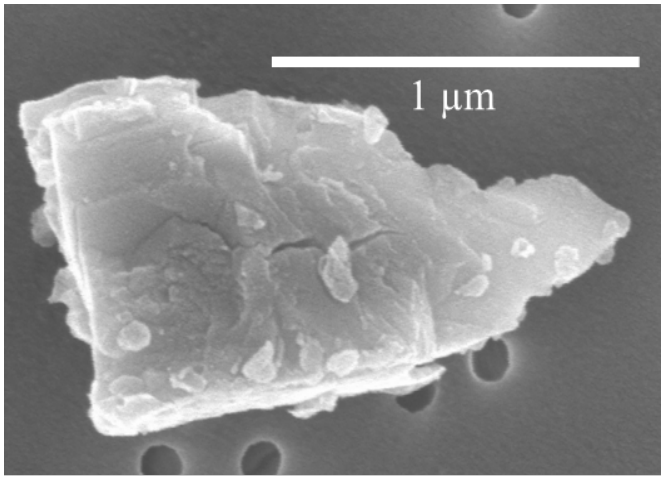
CARES
(Sacramento - T0)

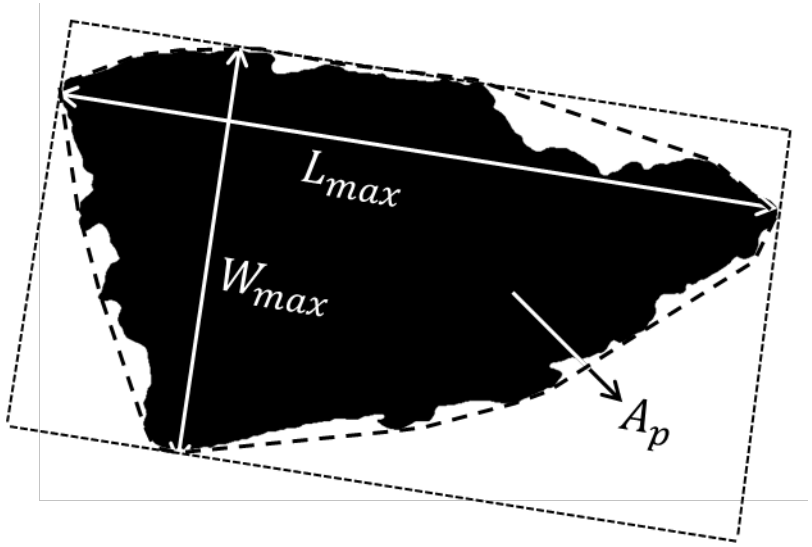


Pico
Azores, North Atlantic

Freshly emitted → **Aged**

Compaction



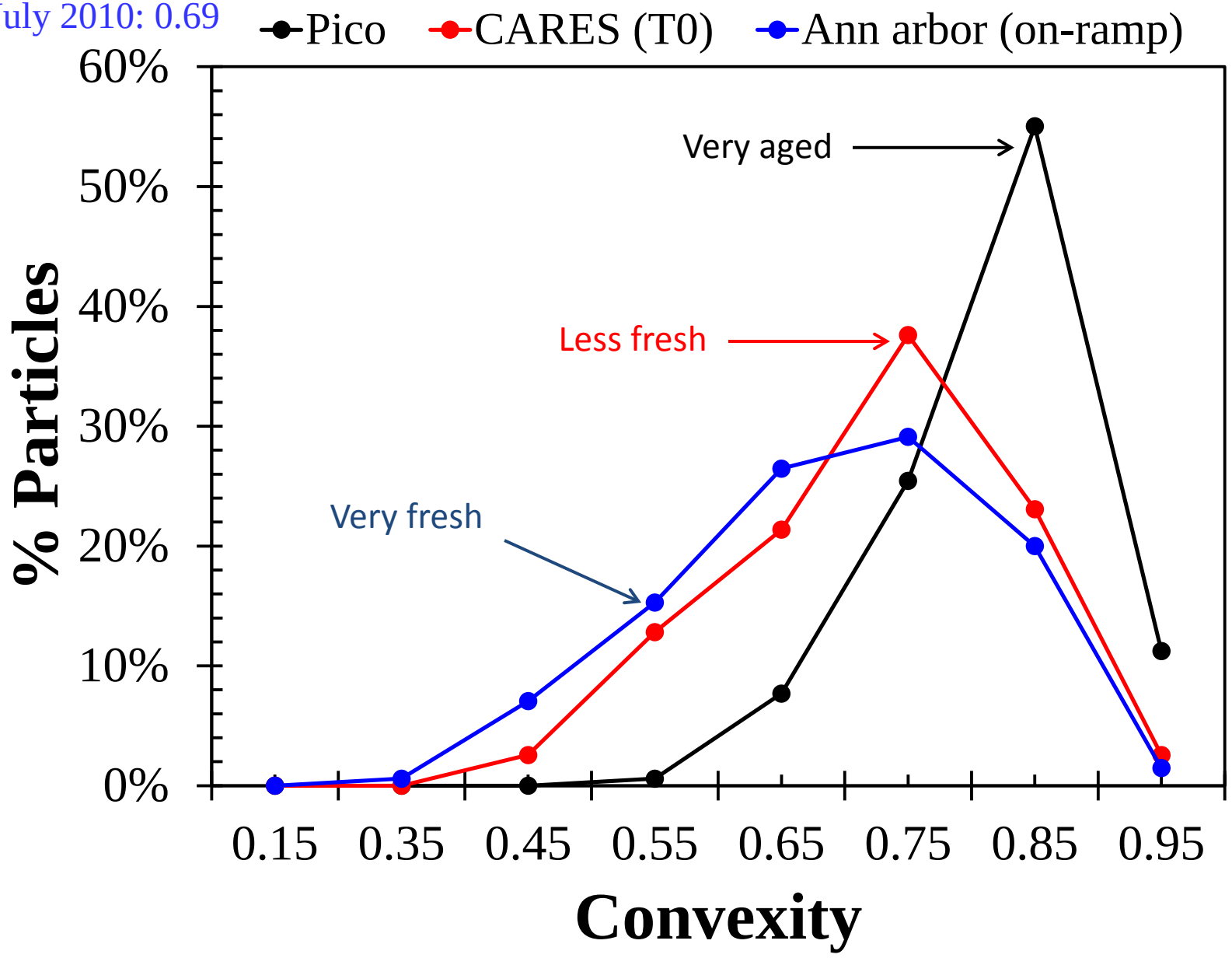


$$Convexity = \frac{A_P}{\text{Convex hull polygon}}$$

Average convexity: Pico July20, 2012: 0.82

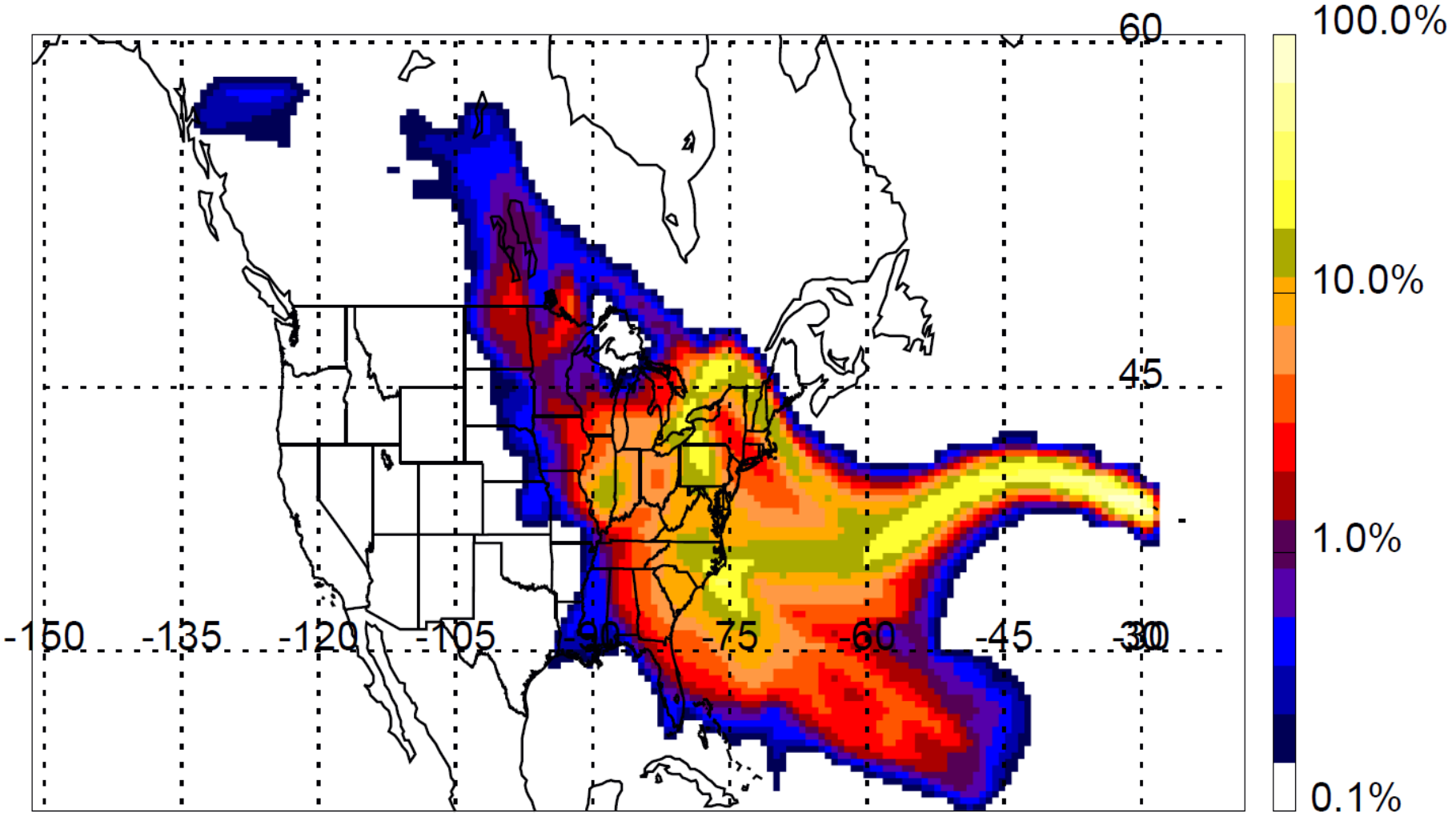
CARES, June25, 2010: 0.72

Ann Arbor, July 2010: 0.69



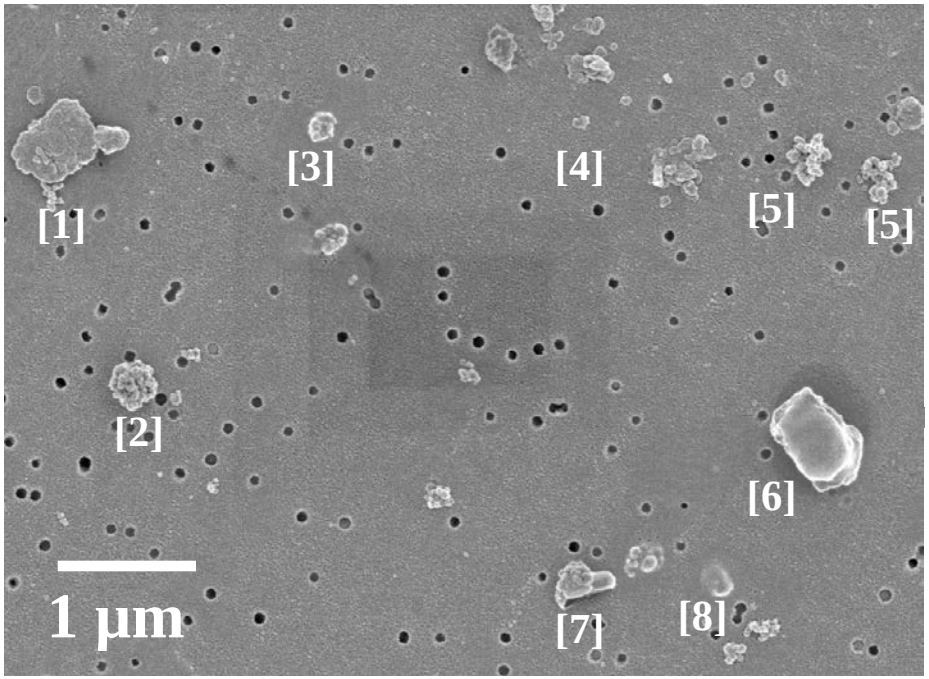
Were is the airmass coming from?

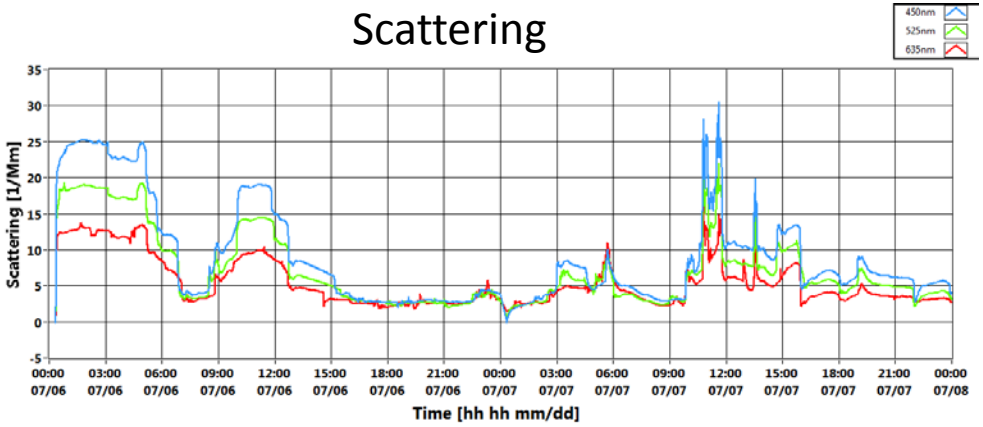
Flexpart retroplume

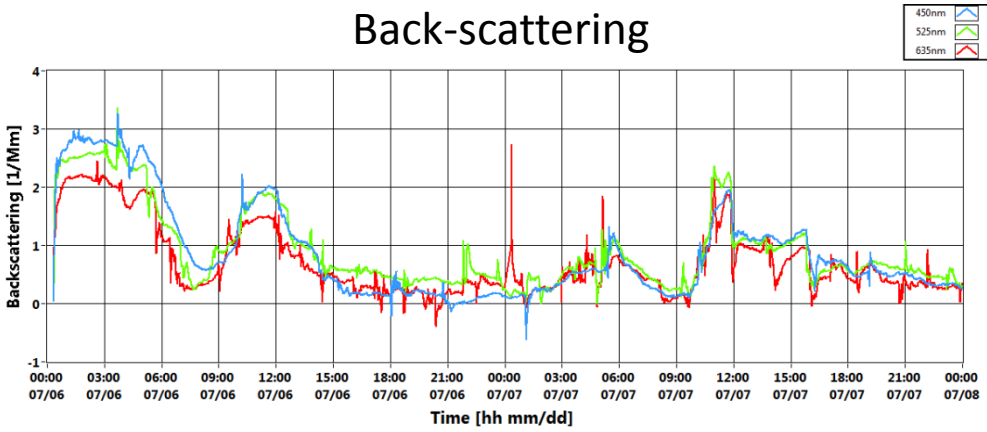


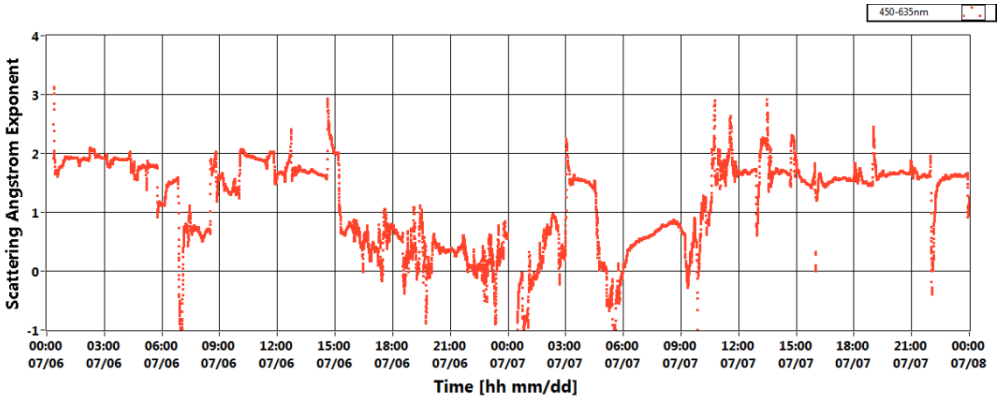
Various morphologies and mixing states

#14 (July 6, 2012)







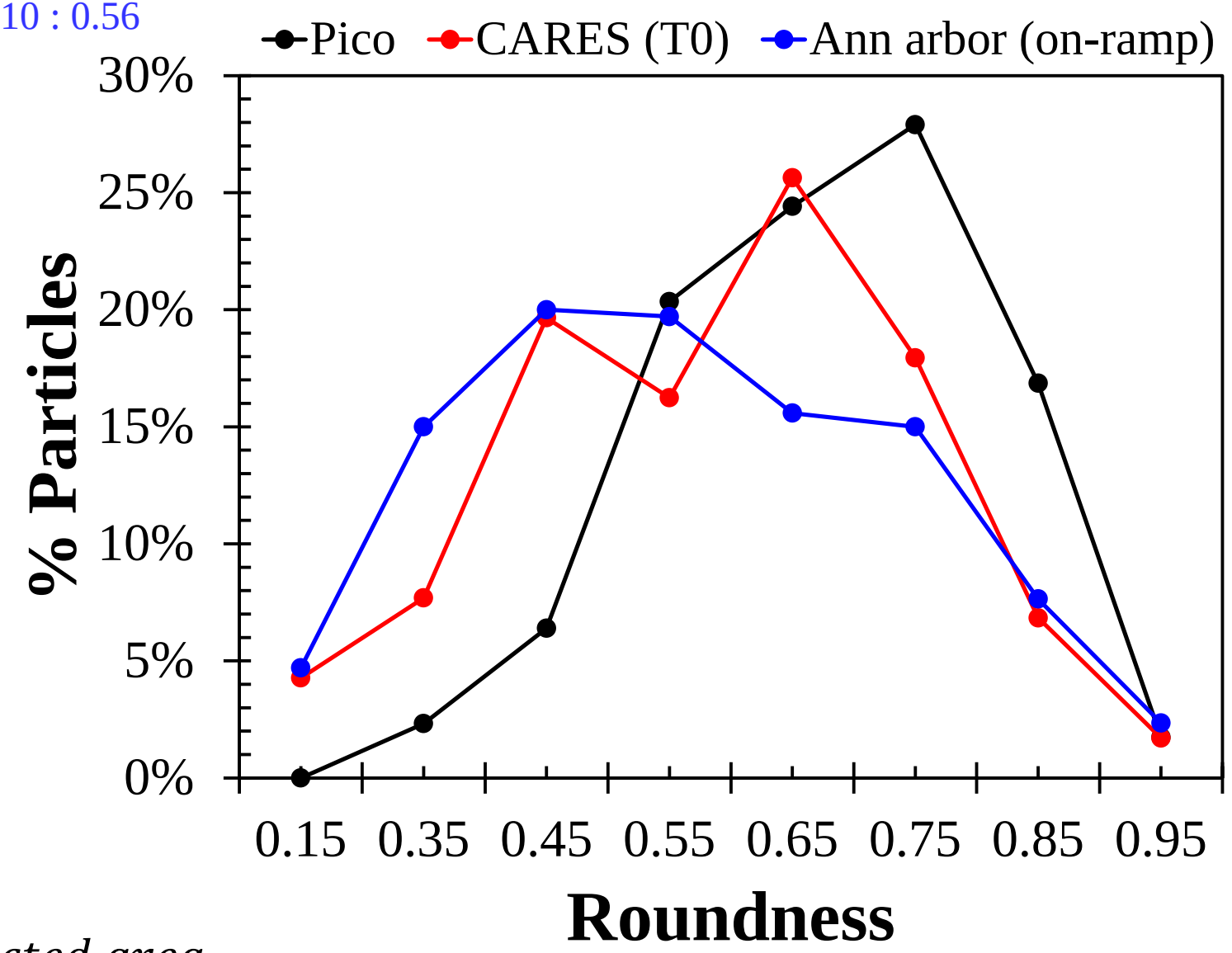


[1] Mineral dust
[2] compacted soot
[3] embedded soot
[4] irregularly shaped particle
[5] relatively more elongated soot
[6] particle with evaporated liquid coating
[7] soot mixed with dust
[8] probably liquid (organic?) aerosol

Average roundness: Pico July20, 2012: 0.68

CARES, June 25, 2010 : 0.59

Ann Arbor, July 2010 : 0.56



$$Roundness = \frac{4 \times Projected\ area}{\pi \times (Maximum\ length)^2}$$

Average roundness: Pico July 6, 2012: 0.72

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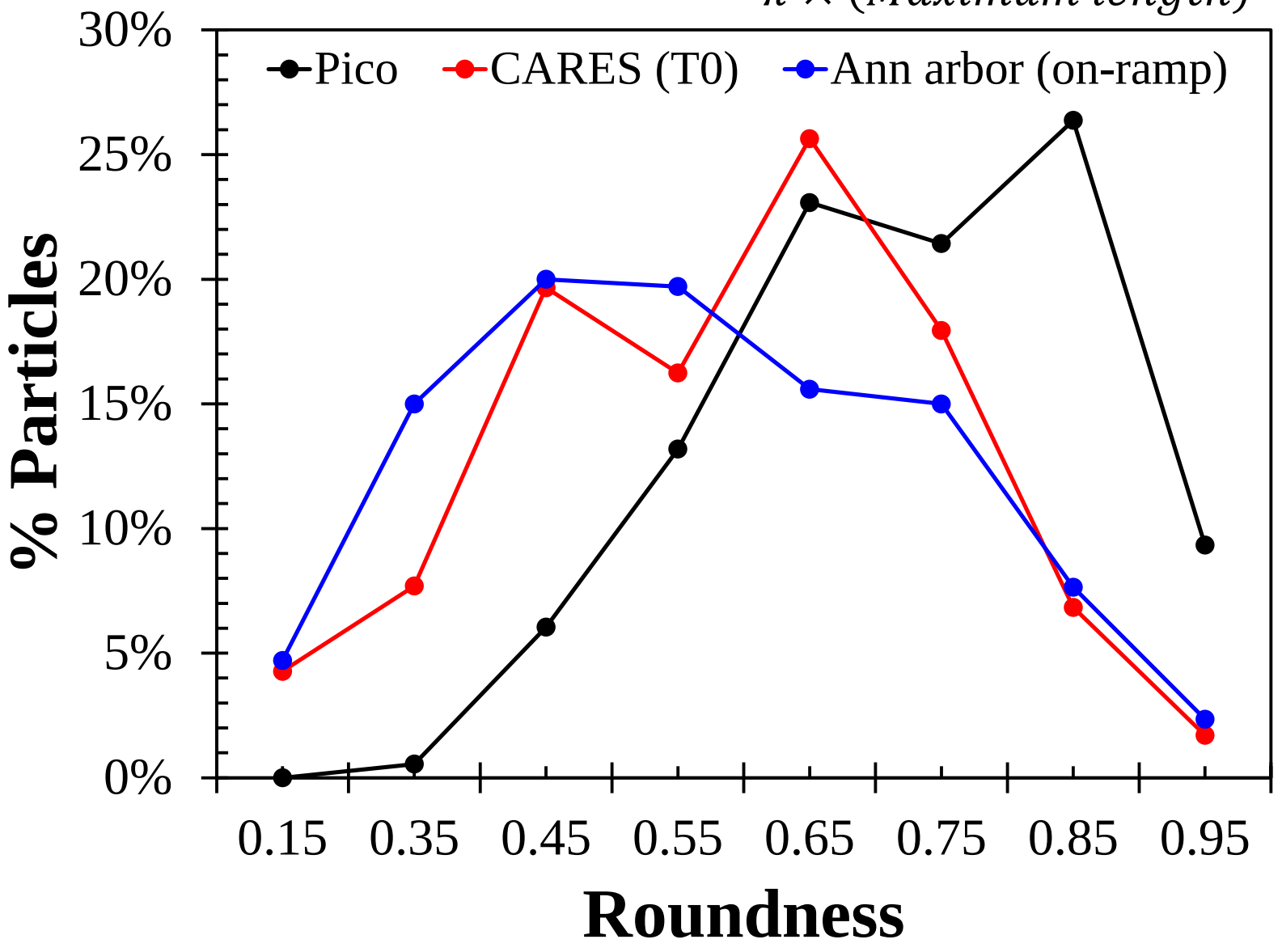
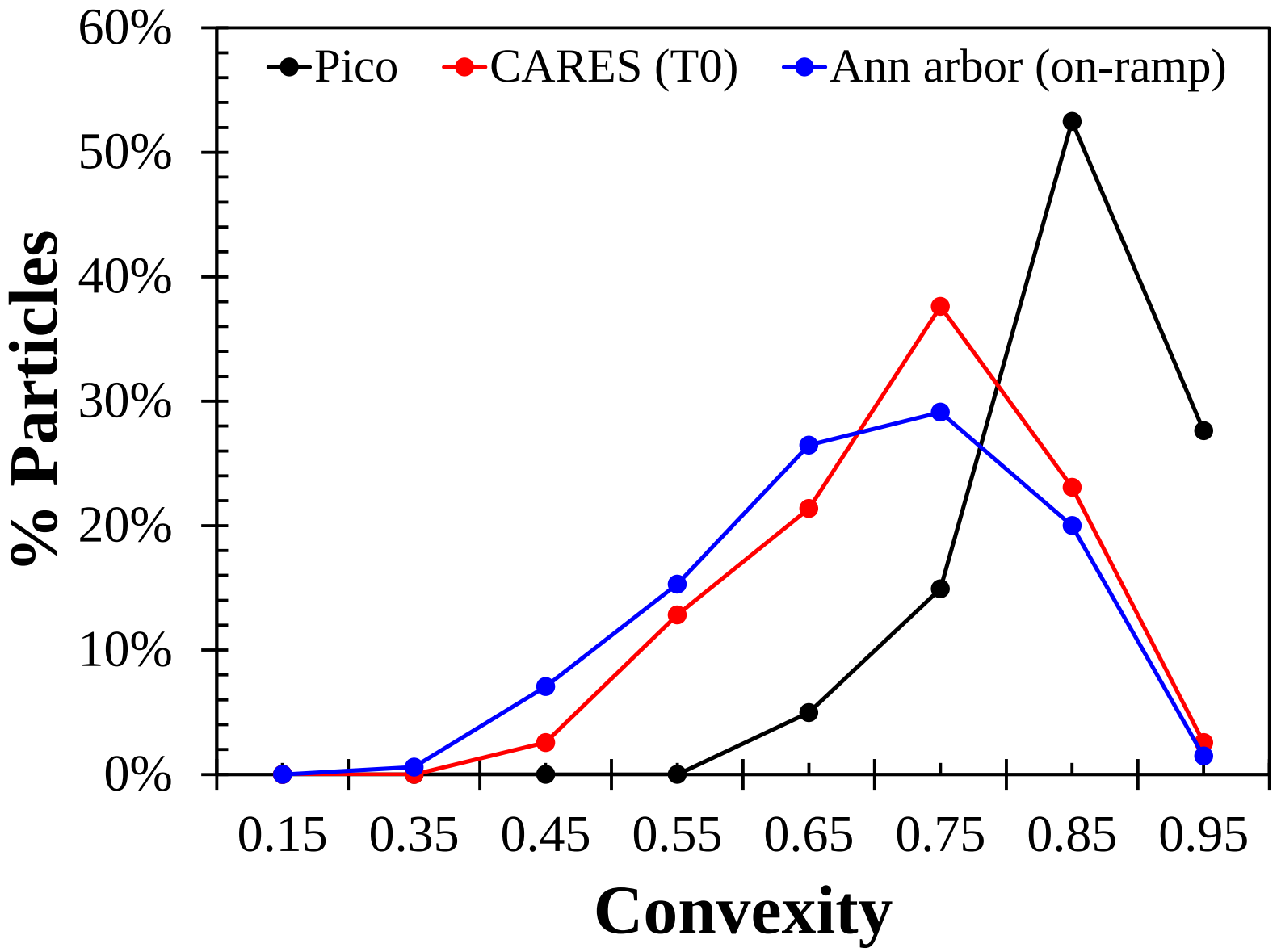
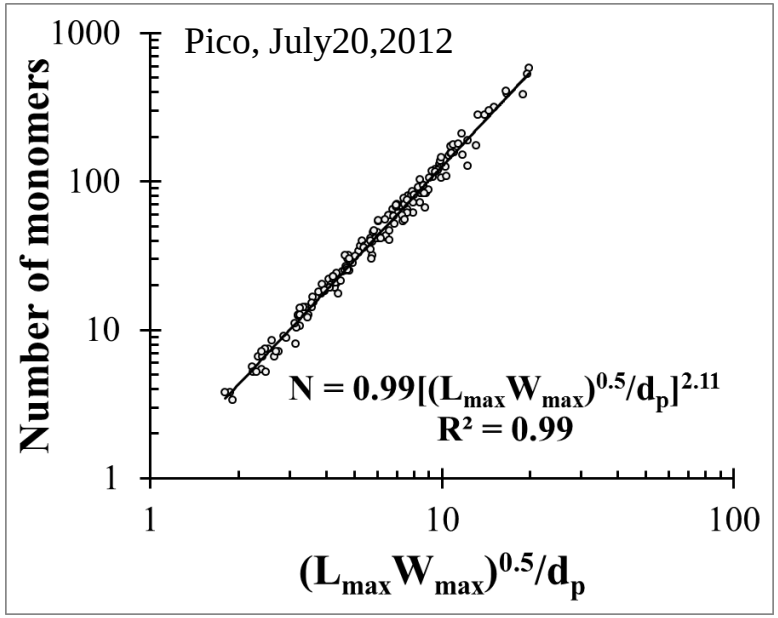
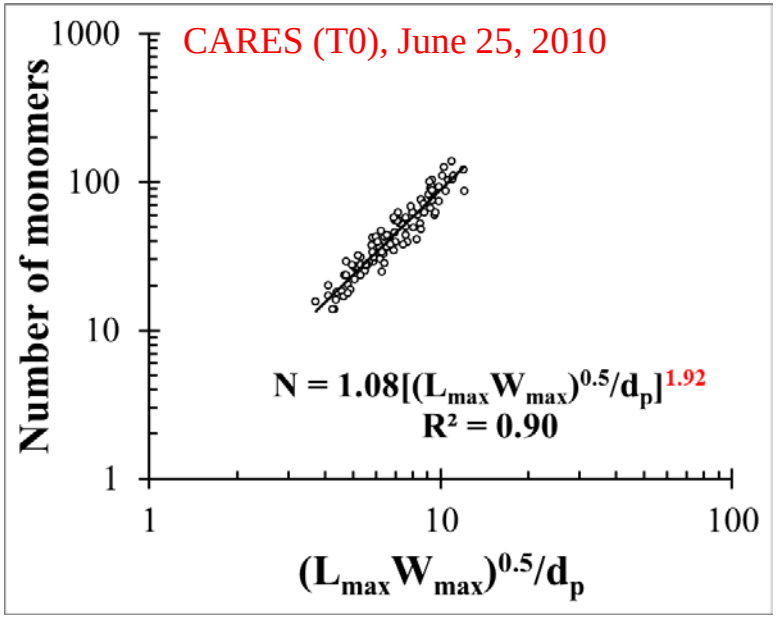


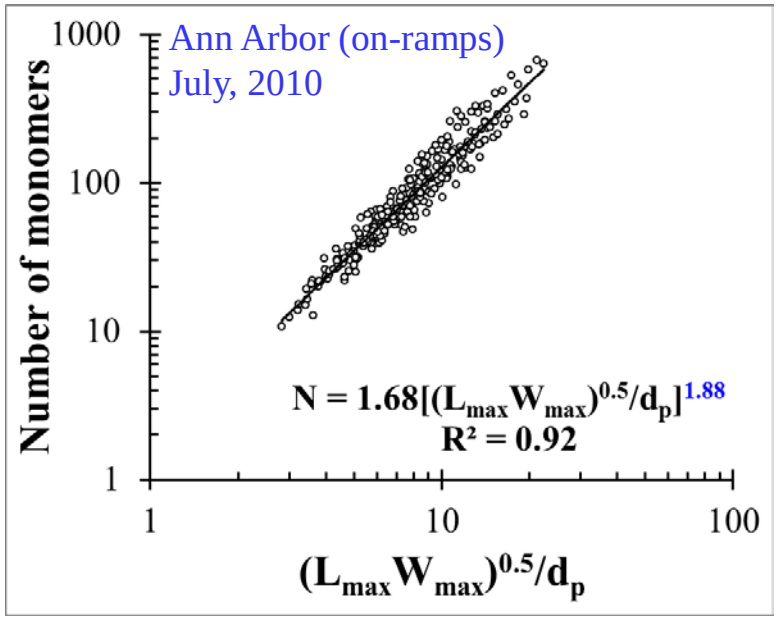
Average convexity: Pico, July 6, 2012: 0.85
CARES, June25, 2010: 0.72
Ann Arbor, July 2010: 0.69



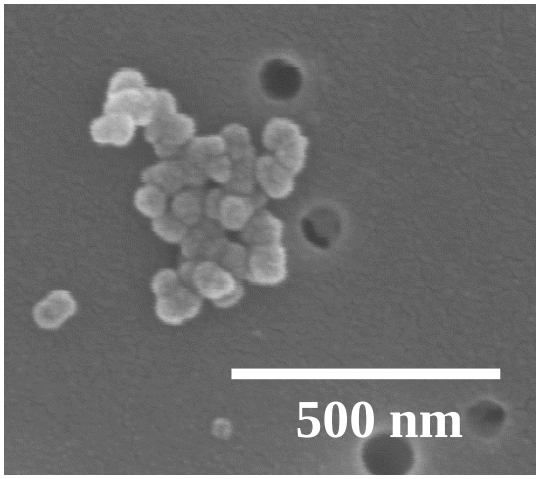
Fractal dimension comparison



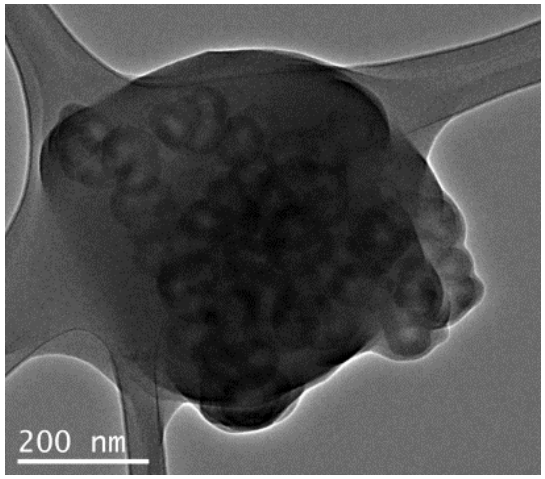




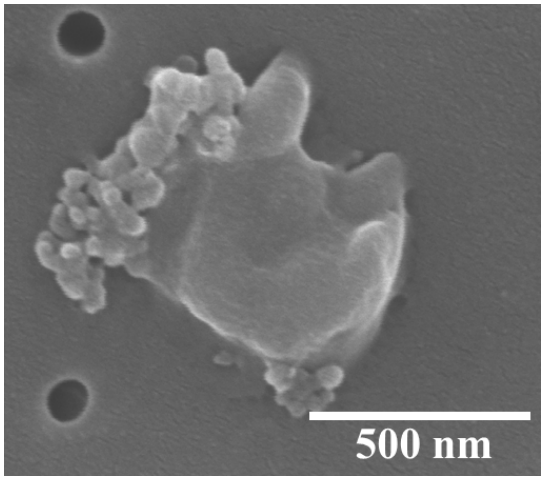
Classification of soot particles



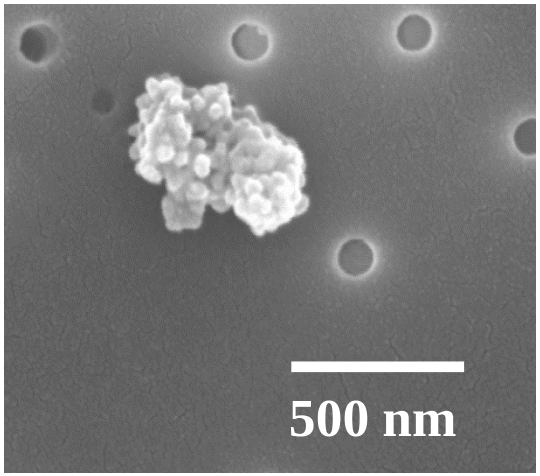
Bare soot, no visual coating (July 6, 2012)



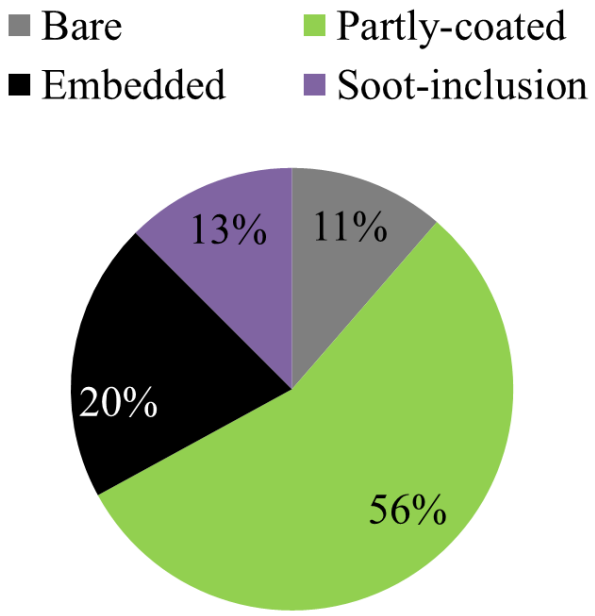
Embedded soot (July 28, 2012)



Soot-inclusion (July 20, 2012)

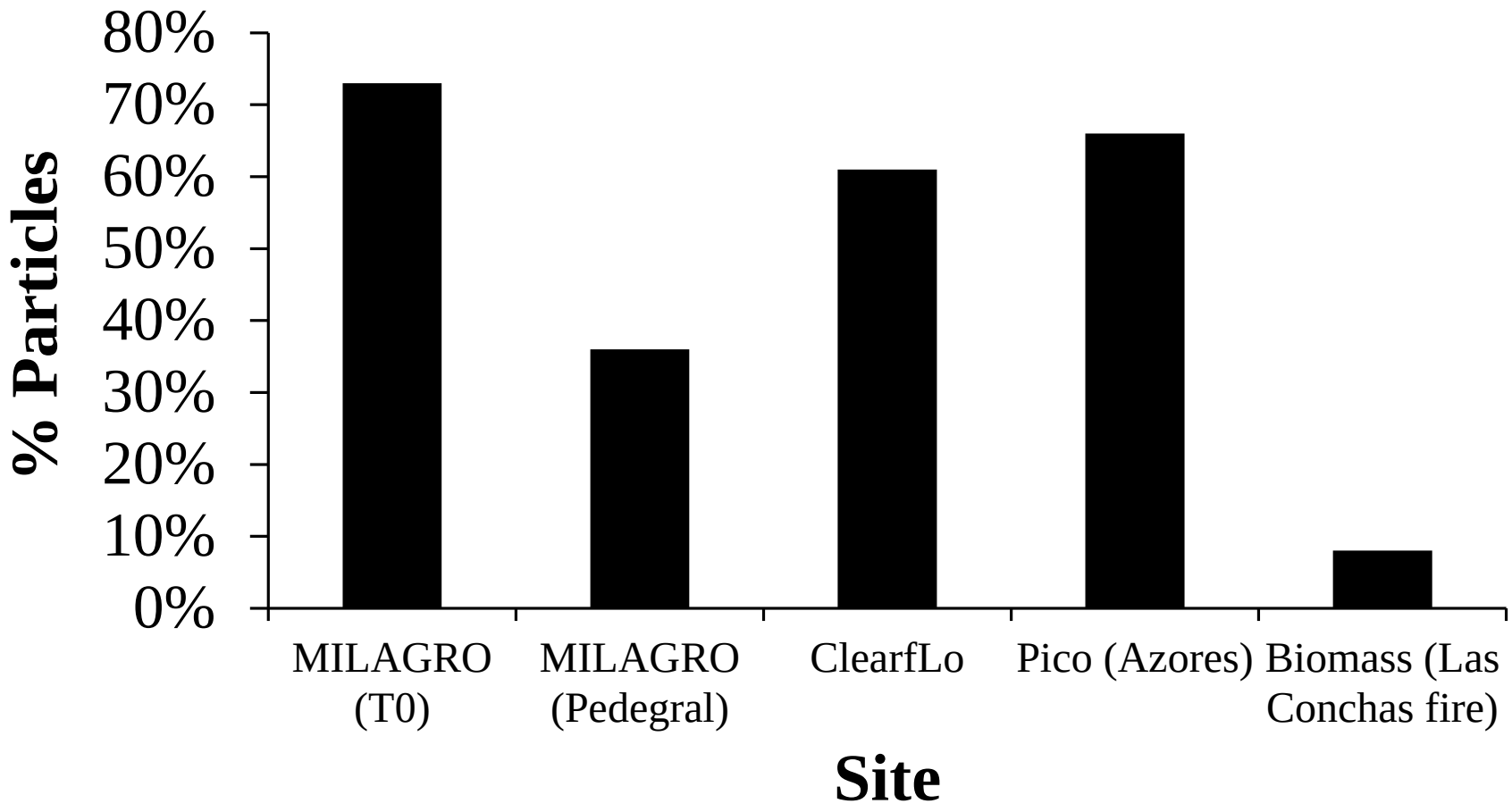


Partly-coated soot (July 20, 2012)

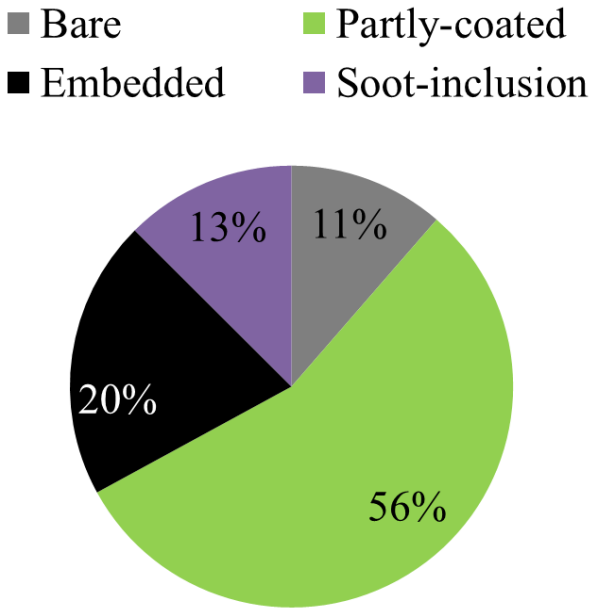


This is for July, 20, #176 particles

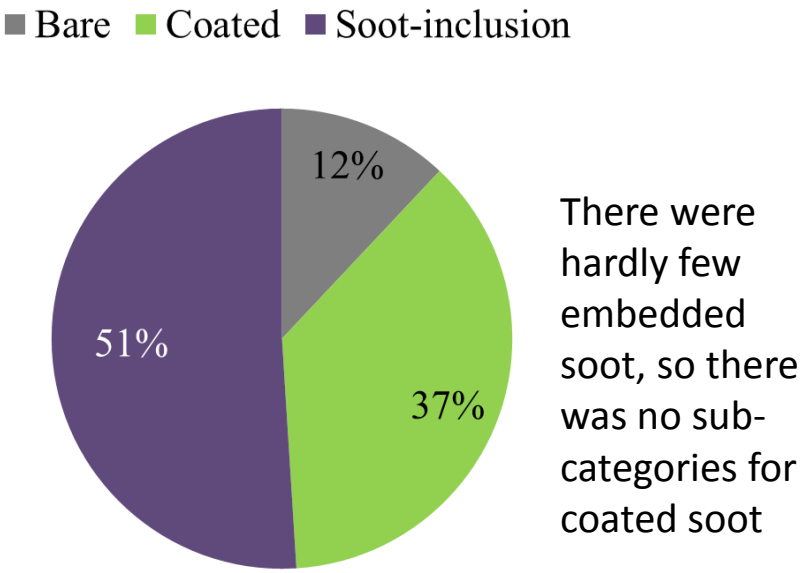
Relative abundance of soot



Pico: July 20, #176 particles

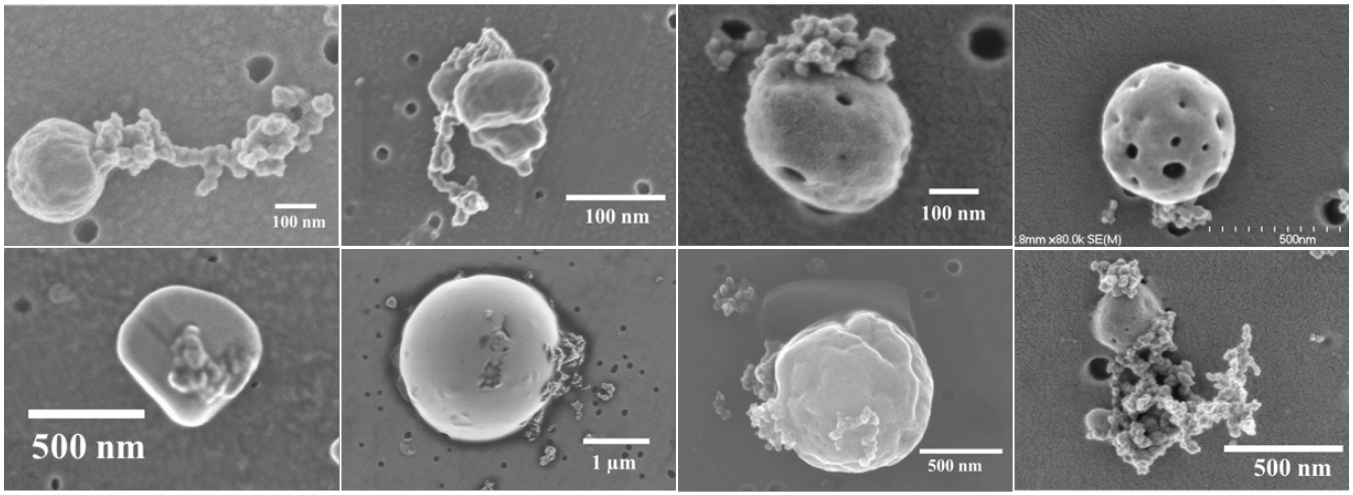


Mexico City (Pedegral, March 2006)

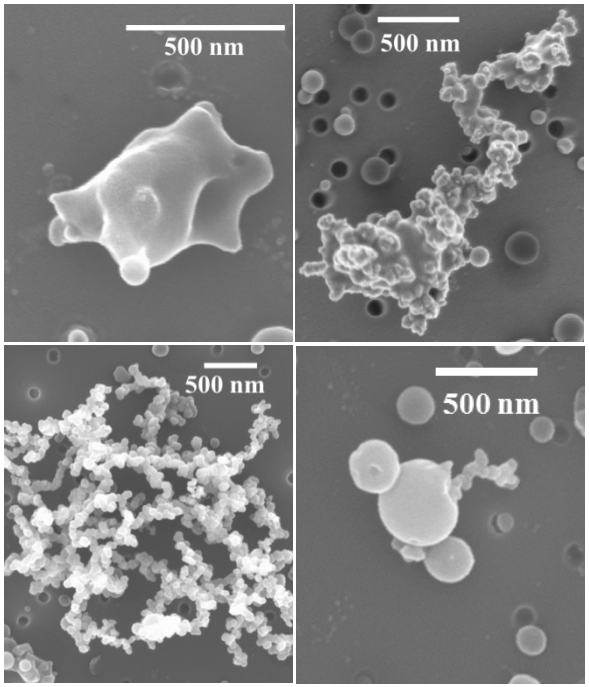


There were hardly few embedded soot, so there was no sub-categories for coated soot

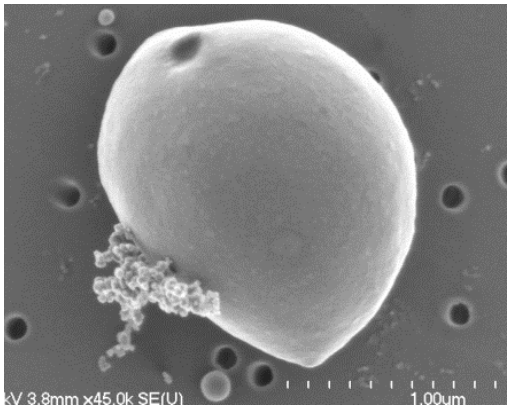
Soot-inclusion in Mexico City



Embedded Partly-coated

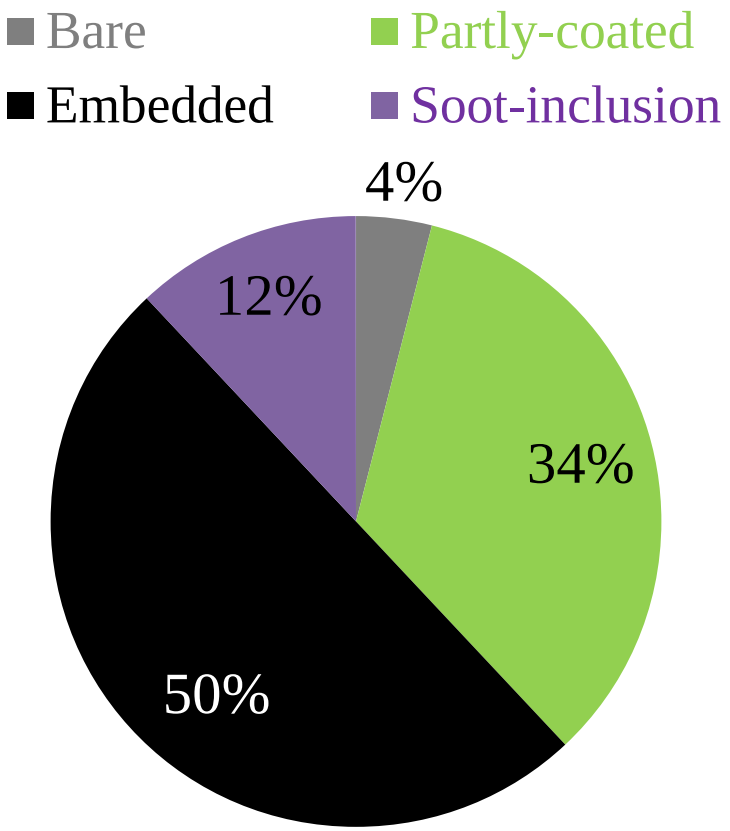


Bare Soot-inclusion



Soot-inclusion (surface inclusion)

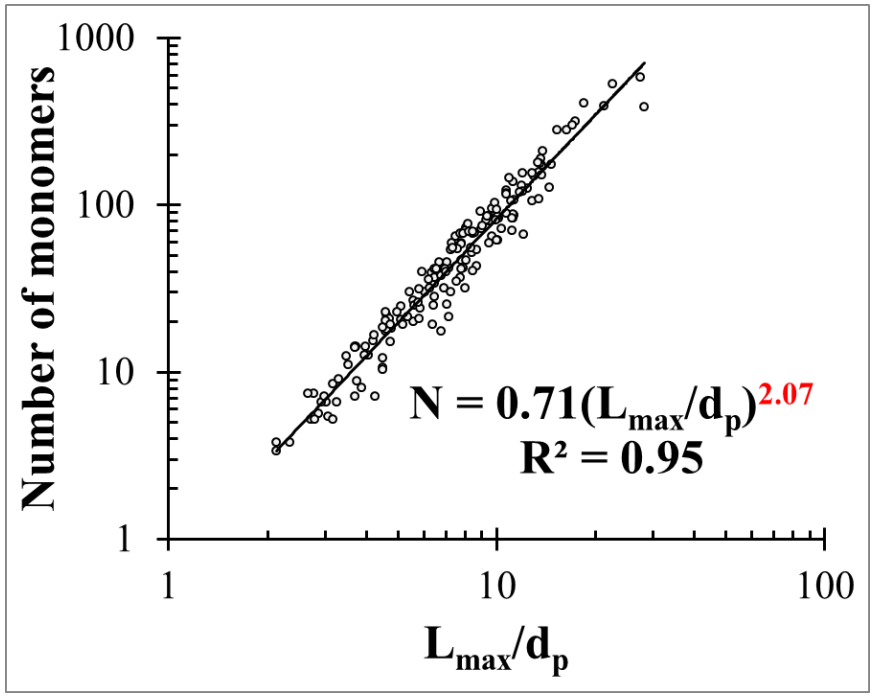
Freshly Emitted Wildfire [Las Conchas Fire, 2011]

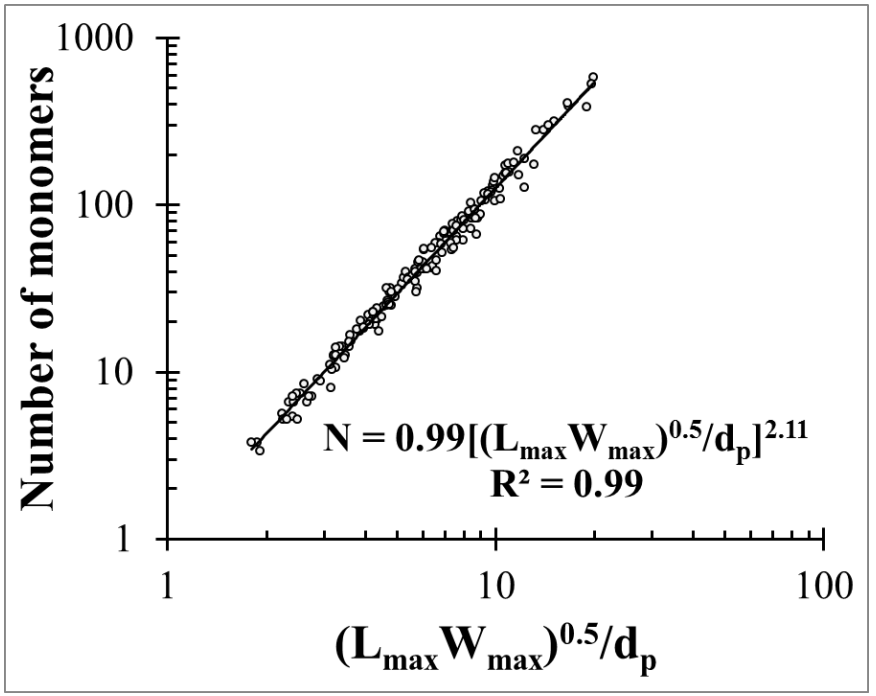


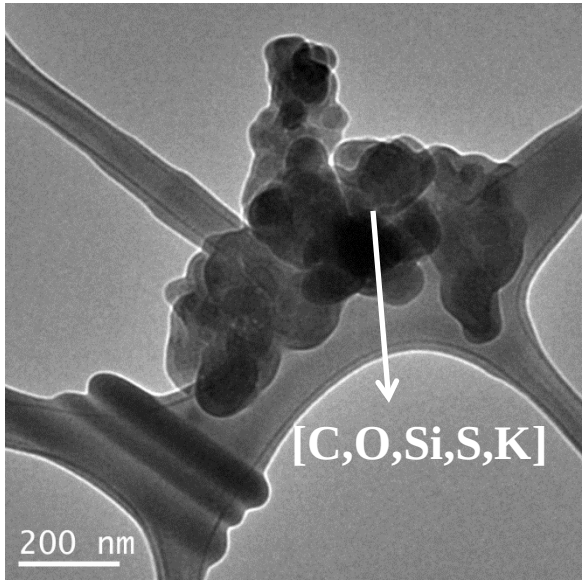
soot particles classified ~1000

8% soot of the total number of particles

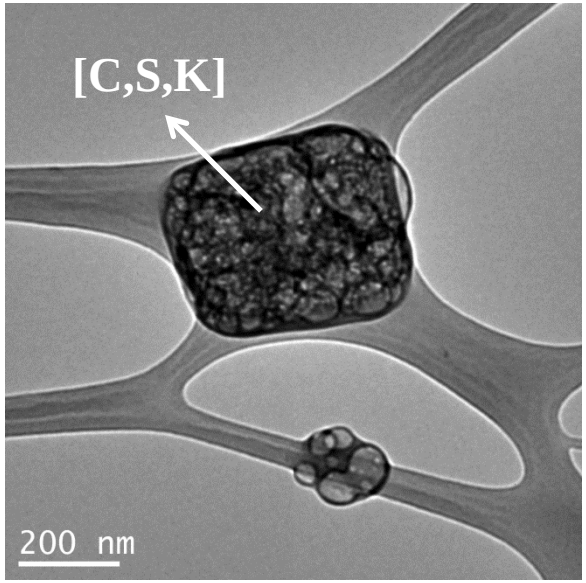
Fractal dimension (July 20, 2012, Pico)



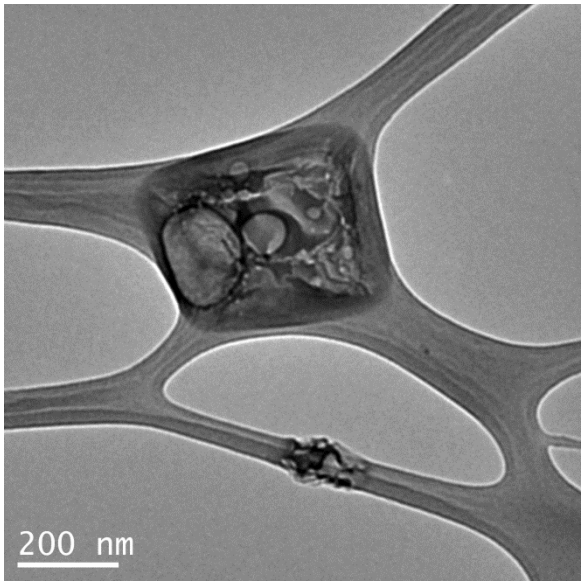




July 27, 2012



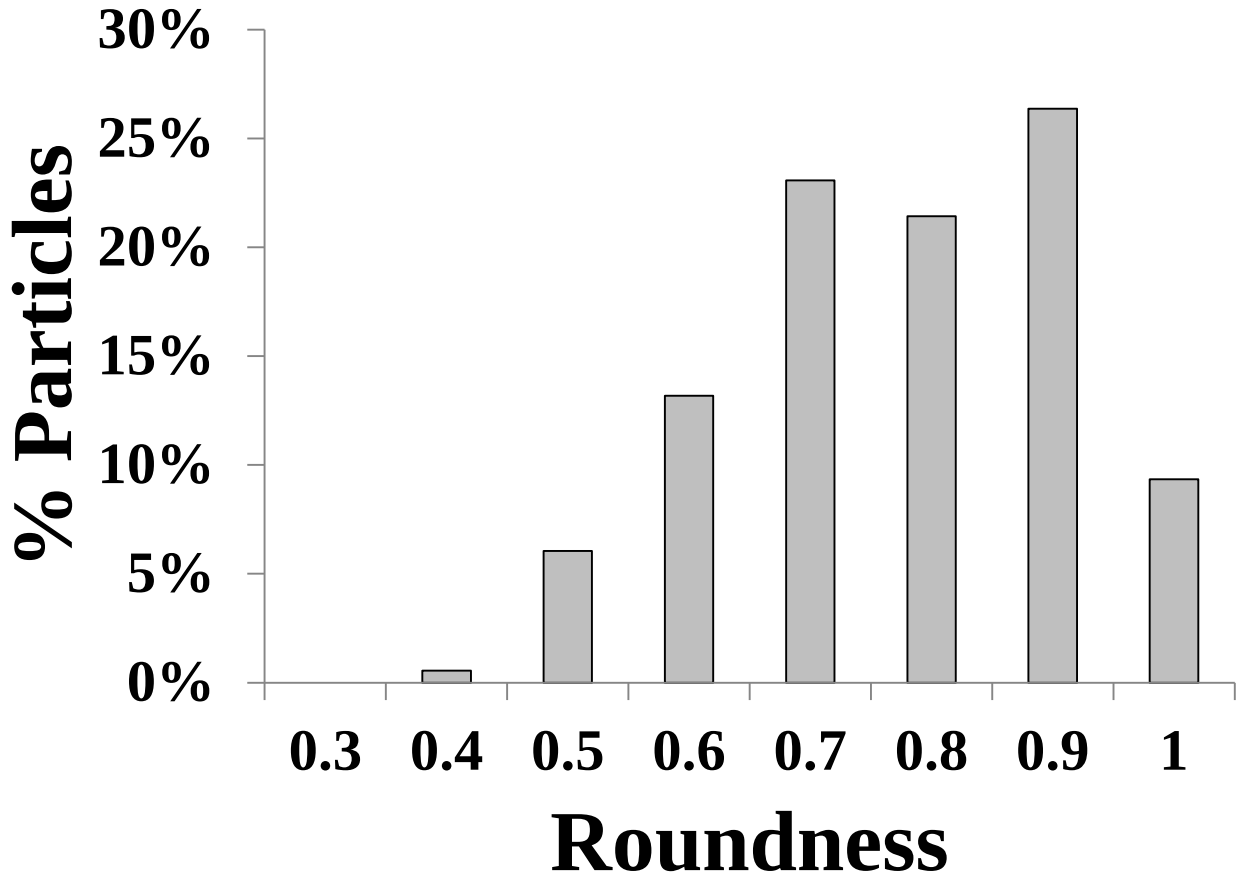
July 27, 2012



After electron beam bombardment

Probably traces of biomass burning aerosol. K is one of the major precursor for fresh biomass burning aerosol, here during transport sulfate aerosol mixed with biomass burning aerosol. I'm not sure why we didn't see the signature of Cl though.

#14 (July 6, 2012)
Avg: 0.72



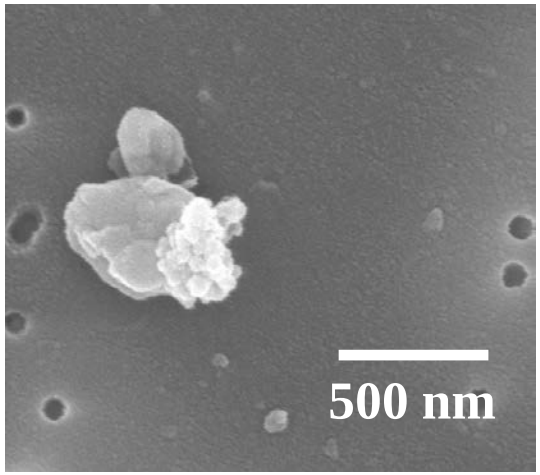
$$Roundness = \frac{4 \times Projected\ area}{\pi \times (Maximum\ length)^2}$$

Average roundness from fresh emissions (from on-ramp vehicle emissions) ~0.55.

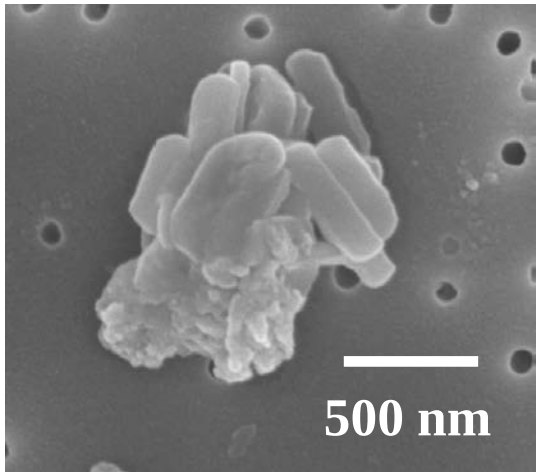
Other mixing:

1) Dust + soot
2) Dust + soot + sulfate

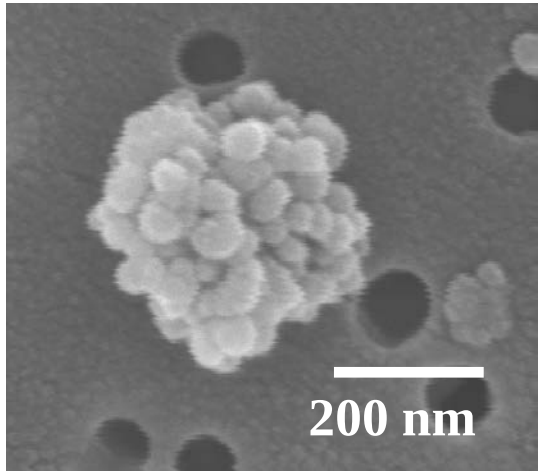
1)



2)



Soot particles were compacted, what is the fraction? next slides shows distribution of roundness



Compacted soot, near spherical (July 6, 2012)